Radar Monitoring of Wetlands for Malaria Control

First Interim Report

November 4, 1997

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Preface

The first Radarsat image was received August 28, 1997. The following report covers the first phase of the analysis of this image.

Introduction

Malaria is perhaps the most serious human disease problem. It inflicts millions worldwide and is on the rise in many countries where it was once under control. This rise is in part due to the high costs, both economic and environmental, of current control programs. The search for more cost-effective means to combat malaria has focussed attention on new technologies, one of which is remote sensing. Remote sensing has become an important tool in the effort to control a variety of diseases worldwide and malaria is perhaps one of the most promising (e.g. Pope et al., 1994a).

This study is part of the malaria control effort in the Central American country of Belize, which has experienced a resurgence of malaria in the last two decades. The proposed project is a feasibility study of the use of Radarsat (and other similar radar systems) to monitor seasonal changes in the breeding sites of the anopheline mosquito, which is responsible for malaria transmission. We propose that spatial and temporal changes in anopheline mosquito production can be predicted by sensing where and when their breeding sites are flooded. Timely knowledge of anopheline mosquito production is a key factor in control efforts. Such knowledge can be used by local control agencies to direct their limited resources to selected areas and time periods when the human population is at greatest risk. Radar is a key sensor in this application because frequent cloud cover during the peak

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periods of malaria transmission precludes the use of optical sensors.

Approach

There are at least four major anopheline mosquitos that are responsible for malaria transmission in Belize: <u>Anopheles albimanus</u>, <u>An. darlingi</u>, <u>An. psuedopuntipennis</u>, and <u>An. vestitipennis</u>. Each has a specific habitat type where it prefers to lay its eggs. These breeding sites have been studied extensively by ecologists and entomologists in the Remote Sensing for Research and Control of Malaria (RESCOM) project, with which this Radarsat project is affiliated (e.g. Rejmankova et al., 1993, 1995, 1996). In the northern Belize region that is the focus on the current Radarsat research, the primary mosquito vectors are <u>An. albimanus</u> and <u>An. vestitipennis</u>. <u>An. albimanus</u> breeds in marshes with low sparse cover of macrophytes and abundant floating algal mats (Rejmankova et al., 1996). <u>An. vestitipennis</u> breeds in either marshes with tall, dense macrophytes, or in flooded forests (Rejmankova et al., in prep.). Therefore the focus on the Radarsat research is to monitor conditions in these two marsh types, and if possible in the forests as well.

Prior experience has shown that it is very difficult to identify specific wetland types with single channel radars such as

Radarsat. Hence we use the approach first advanced by Pope et al. (1992): spaceborne optical sensors are used to identify and map mosquito breeding habitats with dry season imagery and then radar is used to monitor conditions within these habitats.

Optical Image Analysis

SPOT multispectral images acquired in February 1990-1992 were analyzed to identify and map An. albimanus and An. vestitipennis breeding habitats. The SPOT images were first georeferenced using GPS measurements made in the field and location information in 1:50,000 topographic maps. Registration errors were less than one pixel (20 m). Next an unsupervised isoclass clustering technique was used to convert the three-band multispectral images into individual classified images with 45 classes. These classes were then grouped interactively into 7 land cover types using field observations (with GPS coordinates) and color infrared photographs. The multispectral SPOT data were extracted from the tall marsh and forest classes and subjected to a second iteration of the isoclass clustering to refine the classification. The final classification includes 10 land cover types (Figure 1A): 1) urban/bare ground; 2) pasture/fallow; 3) cropland; 4) forest; 5) swamp forest; 6) savanna; 7) tall dense marsh; 8) tall sparse marsh; 9) low sparse marsh; and 10) water. Of particular interest are the important anopheline breeding habitats types 5, 7, and 9.

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Radarsat Image Analysis

Approximately 30 Radarsat images have been acquired over Belize beginning in October 1996 with about 2 acquisitions per month. Nevertheless, due to problems with extracting the images from the data bank in Canada, only one Radarsat image (four image segments, acquired on January 28th, 1997) has been obtained from the Alaska SAR facility. This analysis is based upon this image. The Radarsat image was converted to an 8-bit raster and resampled to the 20 m SPOT image resolution. The Radarsat image was then coregistered to the SPOT images using prominent geographic features easily recognizable in both images. A 3 pixel by 3 pixel median filter was used to reduce speckle noise. Next a smaller image segment (14.4 km by 34 km) was cut out of the classified SPOT image (Figure 1A) and the Radarsat image (Figure 1B and 1C) for detailed analysis.

Radar backscatter statistics were extracted for each of the 7 natural land cover types (excluding urban/bare ground, pasture/fallow, and cropland). The results are presented in Table 1. A density slice Radarsat image was produced to accentuate the major backscatter differences present in the image (Figure 1C).

Discussion

Late January, when the Radarsat image was acquired, is a transition period between the peak of the wet season (September/October) and the peak of the dry season (March/April). Examination of the late January Radarsat image shows that backscatter from the marsh types is highly variable. This can be readily seen by comparing the red zones in the density slice image (Figure 1C) with the classified SPOT image. Note that the tall sparse marsh (purple) and short sparse marsh (red) areas in the SPOT image often (but not always) contain radar bright (red in Figure 1C) patches.

Flooded marshes typically give very bright radar returns due to double bounce radar reflections (forward scattering) off the water and the stems of the emergent macrophytes (Pope et al., 1994b, 1997). The bright radar patches in the marsh areas are interpreted as flooded zones. The bright radar returns in the upper left (northwest) corner of the Radarsat image are flooded rice fields, which provide the same water-stem geometry as the flooded marshes.

The data in Table 1 serve as baseline measurements for the backscatter characteristics of land cover types in the study site for January 28, 1997. The highest average returns are from the low sparse marsh (type 9), which may indicate relatively high amount of

flooding. Relatively high radar returns are found for the tall sparse marsh, which is probably also partly flooded. The lower returns from the tall dense marsh (type 7) may indicate that either this marsh is not flooded, or that it is too dense for significant C-band radar penetration. The lowest radar returns are for open water, due to forward scattering away from the radar antenna.

The future analysis of radar images from the peak wet and dry seasons will allow for testing of the interpretations and speculations noted above. Specifically, we expect the average backscatter in the marsh areas to decrease and become more patchy as water levels drop. After the rains resume (usually by June), we expect the average backscatter to increase. Patchiness should decrease as the peak of the wet season is reached in September/October. Similar changes may occur in the swamp forests, however it is uncertain whether or not C-band will provide enough penetration to detect flooding beneath the tree canopy.

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Table 1. Radarsat backscatter from natural land cover types. Northern Belize Rio Hondo test site.

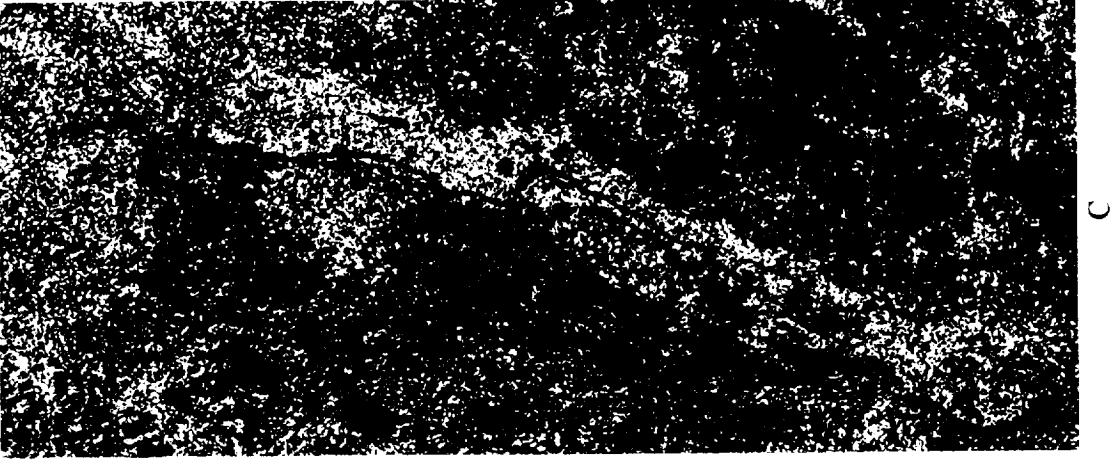| Land Cover	Backscatter (DN)	Percent of site
Forest	58.5 ±0.02	26
Swamp Forest	61.2 ±0.07	3
Savanna	59.3 ±0.06	2
Tall Dense Marsh	57.9 ±0.07	2
Tall Sparse Marsh	62.2 ±0.03	15
Low Sparse Marsh	63.4 ±0.07	4
water	40.0 ±0.13	2
Urban/bare ground, pasture/fallow, cropland		46
Full test site	57.4 +0.03	100

Figure 1. Satellite images of the Rio Hondo malaria test site, northern Belize (image height 34 km, north at top). A. Classified SPOT multispectral image. Key: White - urban/bare ground; yellow - pasture/fallow; brown - cropland; dark green - forest; light green - swamp forest; orange - savanna; pink - tall dense marsh; purple - tall sparse marsh; red - low sparse marsh; and blue - water. B. Radarsat image (3x3 median filter). C. Radarsat image with density slice showing low backscatter in blue (DN 1-30), moderate backscatter in green (DN 31-65), moderately high backscatter in yellow (DN 66-80), and high backscatter in red (DN >80). Red zones correspond to probable flooded marshes. Blue zones are open water.

Figure 1